

DEPENDENCE OF THE INTENSITY OF THE FIRST ORDER DIFFRACTION ON THE LENGTH OF THE SOUND FIELD

C RAGHUPATHI RAO

DEPARTMENT OF PHYSICS, NIZAM COLLEGE, OSMANIA UNIVERSITY, HYDERABAD-7

(Received November 13, 1961 ; Resubmitted November 3, 1962)

ABSTRACT. The dependence of the intensity of the first order diffraction on the length of the sound field at normal incidence of the light beam is studied and the positions of intensity maxima and minima are located with the help of a photo-tube. The positions of maxima are observed for the first time and agree fairly well with the values calculated from Raman and Nath's theory.

The nature of increase of $I_{\pm 1}$ with the length of the sound field at oblique incidence is found to be in good agreement with David's expression obtained from Brillouin's theory.

INTRODUCTION

Bär (1933) was the first to show the changes produced in the diffraction of light by a change of the length of the sound field. He produced photographs which clearly show that a variation of the length of the sound field produces a wandering of intensity similar to that observed by a change in the acoustical power of the crystal. Korff (1936) studied this phenomenon in air at a frequency of 4.28 Mc/s. Newmann (1939), using white light, studied the dependence of the total intensity of diffracted light on the length of the sound wave at 10 Mc/s, using the photo-cell for intensity measurements. Rao (1948) studied this phenomenon using the diffraction of light at 35 Mc/s and all the intensities were visually estimated by him. Except for these qualitative observations, no systematic quantitative intensity measurements were available in the literature on high frequency diffraction orders.

In this investigation, the intensity of the first order diffraction with the length of the sound field is quantitatively measured using an R.C.A. 931-A photo-multiplier tube and some of the interesting results obtained are presented here.

THEORY

All the existing theories of diffraction phenomenon clearly show that the length of the sound field forms an important parameter in all the intensity expressions obtained for diffraction orders. Nath (1938), using the generalised theory

of Raman and Nath with suitable modifications, obtained for I_{+1} , the intensity of the first order diffraction, the following expression

$$I_{+1} = \frac{4}{\rho^2 + 8} \sin^2 \left\{ \frac{\sqrt{\rho^2 + 8}}{4} \xi \right\} \quad \dots \quad (1)$$

where $\rho = \frac{\lambda^2}{\mu \mu_0 \lambda^{*2}}$ and $\xi = \frac{2\pi\mu L}{\lambda}$

Thus the length of the sound field L enters in the parameter ' ξ ' showing that the effect of variation of the length of the sound field is analogous to the variation of μ , the maximum change in the refractive index of the liquid medium, which is proportional to the power input to the crystal. The above expression clearly shows that the intensity of the first order goes through successive maxima and minima periodically, the condition for the maximum intensity being

$$\frac{\sqrt{\rho^2 + 8}}{4} \xi = n \cdot \pi/2 \text{ where } n \text{ is any odd integer;}$$

which gives for the length of the sound field the expression

$$L = \frac{n}{\sqrt{\left(\frac{\lambda}{\mu_0 \lambda^{*2}}\right)^2 + 8 \left(\frac{\mu}{\lambda}\right)^2}} \quad \dots \quad (2)$$

The condition for minimum of zero intensity is given by $\frac{\sqrt{\rho^2 + 8}}{4} \xi = n\pi$ where n is any integer, which gives for the length of the sound field the expression

$$L = \frac{2n}{\sqrt{\left(\frac{\lambda}{\mu_0 \lambda^{*2}}\right)^2 + 8 \left(\frac{\mu}{\lambda}\right)^2}} \quad \dots \quad (3)$$

The expressions (2) and (3) are very important in that they give specific values to L for the intensity of the diffraction order to attain its maximum and minimum respectively. At high frequencies beyond 23 Mc/s, the second term in expressions 2 and 3 within the root becomes negligible when compared to the first. Its contribution is about 1.4% of the first at 23 Mc/s for water, and becomes still less at higher frequencies and for liquids of low ultrasonic velocity. As such, neglecting the second term, the expressions 2 and 3 can be simplified and written as

$$L = \frac{n \mu_0 \lambda^{*2}}{\lambda}, \text{ where } n \text{ is any odd integer} \quad \dots \quad (4)$$

and $L = 2n \cdot \frac{\mu_0 \lambda^{*2}}{\lambda}$, where n is any integer ... (5)

respectively. These expressions (4) and (5) predict the intensity maximum and minimum of the diffraction order for definite lengths of the sound field. The same result has been obtained by Rylov (1936) and David (1937).

The intensity of the first order diffraction attains its maximum at regular intervals as given by expression (4) and passes through minima or becomes zero at regular intervals as given by expression (5), when the length of the crystal is gradually increased. These positions of maxima and minima of the diffraction order could easily be detected with the help of the photo-tube. The positions of maxima have not been so far observed by any of the investigators.

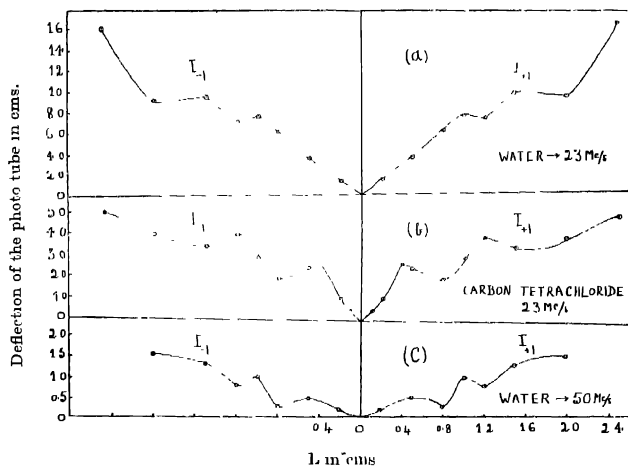


Fig. 1.—Intensity variation of $I_{\pm 1}$ at normal incidence with the length of the sound field.

EXPERIMENTAL RESULTS AND DISCUSSION

Intense first order diffraction lines are produced at 23.0 and 50.0 Mc/s and using the photo-tube, observations are made on the intensity of the first order diffraction at normal incidence of the light beam, varying the length of the sound field. A suitable choice of the liquid medium and the sound frequency facilitates observation of several intensity maxima and minima in a given length of the sound field as the parameter ' L ' depends upon the square of λ^* —the sound wave length in the medium. A one inch square X-cut quartz plate with a fundamental of 1.2 Mc/s is used to generate ultrasonics.

The positions of maxima and minima are located by the photo-tube using water as the seat of ultrasonics. These positions are regularly spaced and are closer at 50 Mc/s than at 23 Mc/s shown in Fig. 1(c) and a). Fig. 1(b) shows the curve obtained by the photo-tube at 23 Mc/s in carbon-tetrachloride. The

positions of maxima and minima are closer in carbon-tetrachloride than the corresponding positions in water.

The experimentally located positions of maxima and minima agree fairly well with the theoretical values of ' L ' calculated from expressions (4) and (5) and show clearly their dependence on the square of λ^* , the sound wave length in the medium.

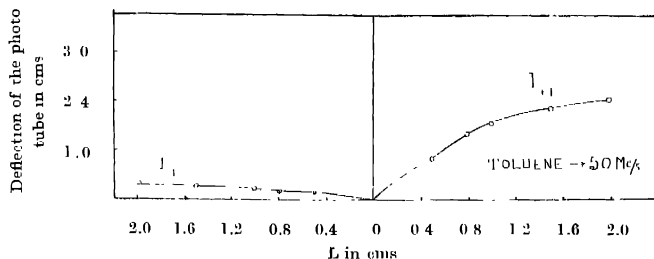


Fig 2—Intensity variation of $I_{\pm 1}$ at oblique incidence with the length of the sound field.

The behaviour of I_{+1} and I_{-1} with the length of the sound field in the oblique incidence position is shown in Fig. 2 for toluene at 50 Mc/s. The intensity of both the diffraction orders increases parabolically with L , though the increase of I_{+1} is far more rapid than that of I_{-1} . This experimental result is in good agreement with the David's expression for $I_m = (\pi\mu L)^2/\lambda^2$ showing that the maximum intensity of the first order diffraction depends upon the square of the length of the sound field.

In conclusion, my thanks are due to Prof S. Bhagavantam for his kind interest in this work.

REFERENCES

- Bar, R., 1933, *Helv Phys. Acta.*, **6**, 570.
- David, E., 1937, *Physik. Zeitschr.*, **38**, 587.
- Karff, W., 1936, *Physik. Zeitschr.*, **37**, 708.
- Nagendra Nath, N. S., 1938, *Proc Ind. Acad Sci.*, **8A**, 499.
- Newmann, E. A., 1939, *Proc Phys. Soc.*, **51**, 794.
- Rao, B. R., 1948, Thesis presented to the Andhra University.
- Rytov, S., 1936, *C. R. Doklady*, **26**, 229.